JET STRUCTURE REPORT TO SIMULATION MEETING

Dennis Perepelitsa and Rosi Reed

Simulation samples

- **High p_T jet samples** allows us to study:
  - The effect of the thinned HCal on the jet response
  - The effect of the ganged EMCal towers on the jet response
  - High p_T jets produced at mid-rapidity, so will not elucidate the effect of ½ EMCal
- **Low p_T jet sample** allows us to study
  - ½ EMCal as these jets will have a wider η range
  - p_T dependence of inclusive jet response

All samples at:

/phenix/upgrades/decadal/dvp/GeneratorInputFiles/

Simulations Generated for Descoping Investigation 1 of 3 – high p_T

N_{evt} = 10k of p_T = 50-55 GeV dijet events Generated with PYTHIA8

- Generate falling jet spectrum with truth-level filtering
  - Keep events with at least one R=0.4 truth jet with 50 GeV < p_T < 55 GeV and $|\eta| < 0.6$.
- HardQCD:all
- PhaseSpace:pTHatMin = 45.0
- PYTHIA events only — want to know jet response from detector, not from UE
- /phenix/upgrades/decadal/dvp/GeneratorInputFiles/

Simulations Generated for Descoping Investigation 2 of 3 – high p_T

N_{evt} = 10k of p_T = 60-65 GeV dijet events Generated with PYTHIA8

- Generate falling jet spectrum with truth-level filtering
  - Keep events with at least one R=0.4 truth jet with 60 GeV < p_T < 65 GeV and $|\eta| < 0.6$.
- Used to test the HCAL performance on very high p_T hadrons
  - Probability of a punch-through increases with p_T

Simulations Generated for Descoping Investigation 3 of 3 – low p_T

N_{evt} = 10k of p_T = 25-30 GeV dijet events Generated with PYTHIA8

- Generate falling jet spectrum with truth-level filtering
  - Keep events with at least one R=0.2 truth jet with 25 GeV < p_T < 30 GeV and $|\eta| < 0.9$.
- Required to fully measure the effect of the reduced EMCal acceptance on the jet response

Single particle simulations

- Response due to single particles also simulated
  - Allows a high statistics check of particles that would high z particles within their given jet
- Simulate π^- at 40 GeV $|\eta| < 0.6$
  - 3 GEANT configurations:
    - Nominal HCAL (260 cm)
    - Thin outer HCAL (240 cm)
    - “Extreme” outer HCAL (220 cm)

GEANT4 Simulations

High p_T jet sample run through 3 Calo configurations:

- Nominal
- 1/2 EMCal
- Thin HCal

Total of 30k G4 dijet events

- /sphenix/sim/sim01/production/aldcharge/pythia8/pythia8dijet/50-55GeV/
- Note: EMCal run with 1D Spacal geometry for memory considerations

Key observable: jet energy *response* p_T^{reco} / p_T^{true}

GEANT4 Simulations

Low p_T sample run through 2 Calo configurations:

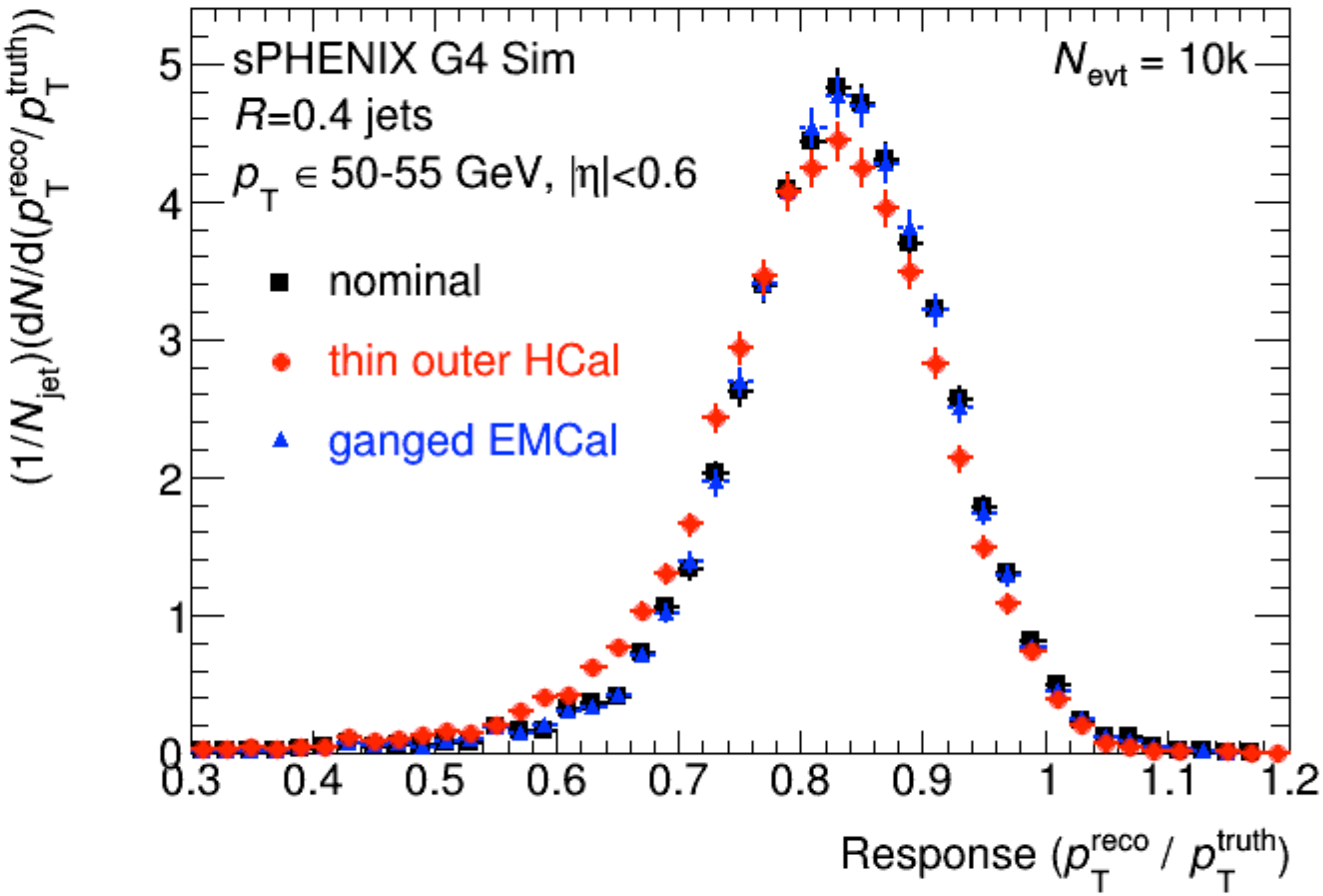
- Nominal
- 1/2 EMCal

Total of 20k G4 dijet events

- /sphenix/sim/sim01/production/aldcharge/pythia8/pythia8dijet/R0p2pT25t30eta0/spacal1d/
- Note: EMCal run with 1D Spacal geometry for memory considerations

Key observable: jet energy *response* p_T^{reco} / p_T^{true} versus η

Inclusive Jet Response vs Calo Configuration



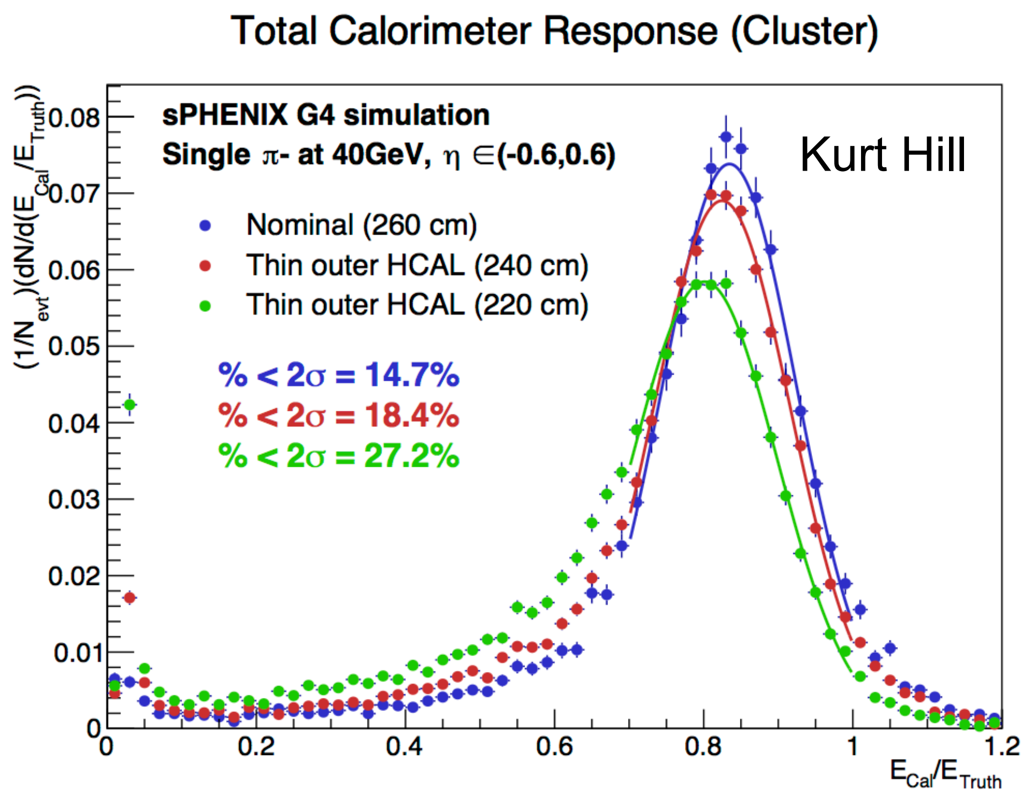
Results are similar for 60 - 65 GeV jets

For inclusive jet measurements

- No significant effect due to the ganged EMCal
- Slight shift and broadening of the Response for thin HCAL

Single hadron response vs HCAL config

- Response starts to rapidly degrade for HCAL thinner than 240 cm
- Punch-through hadrons become significant
  - Difficult to unfold high z particles
  - Symmetric response yields best unfolding results

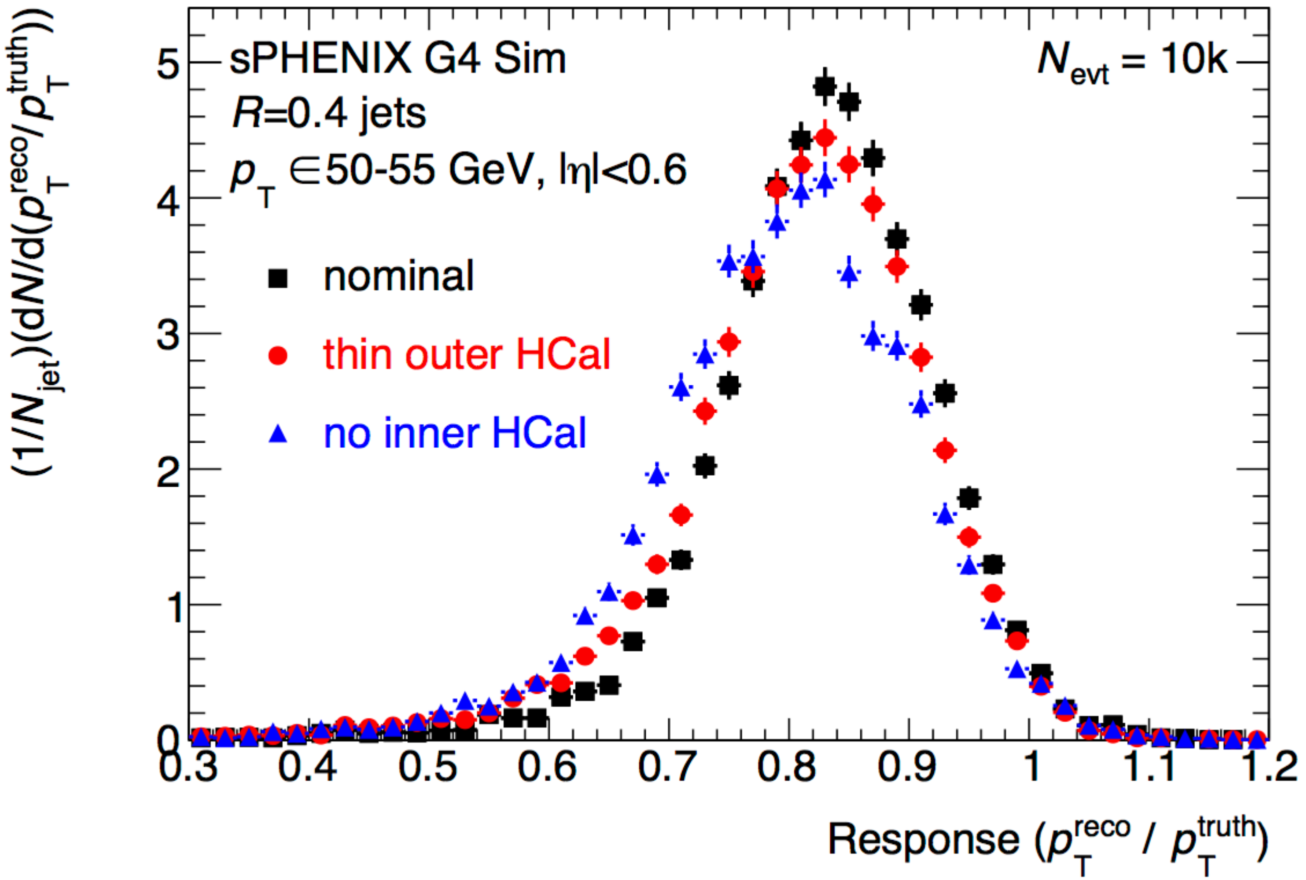


Gaussian Fit Parameters

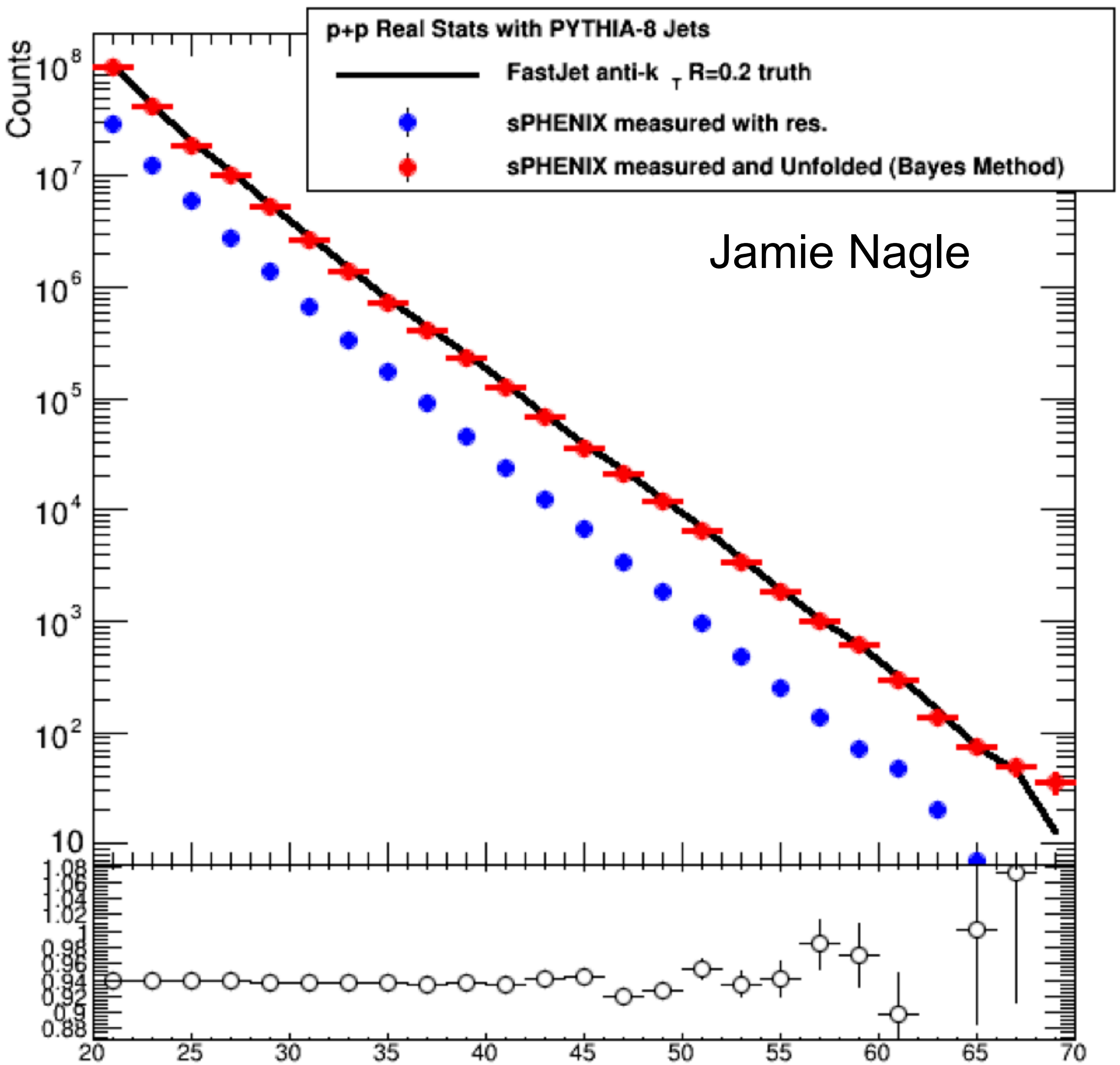
	260 cm	240 cm	220 cm
Mean	0.835	0.825	0.801
Sigma	0.090	0.092	0.097

Jet Response – No Inner HCAL

- Jet Response with no inner HCAL
  - Broader
  - Larger JES shift

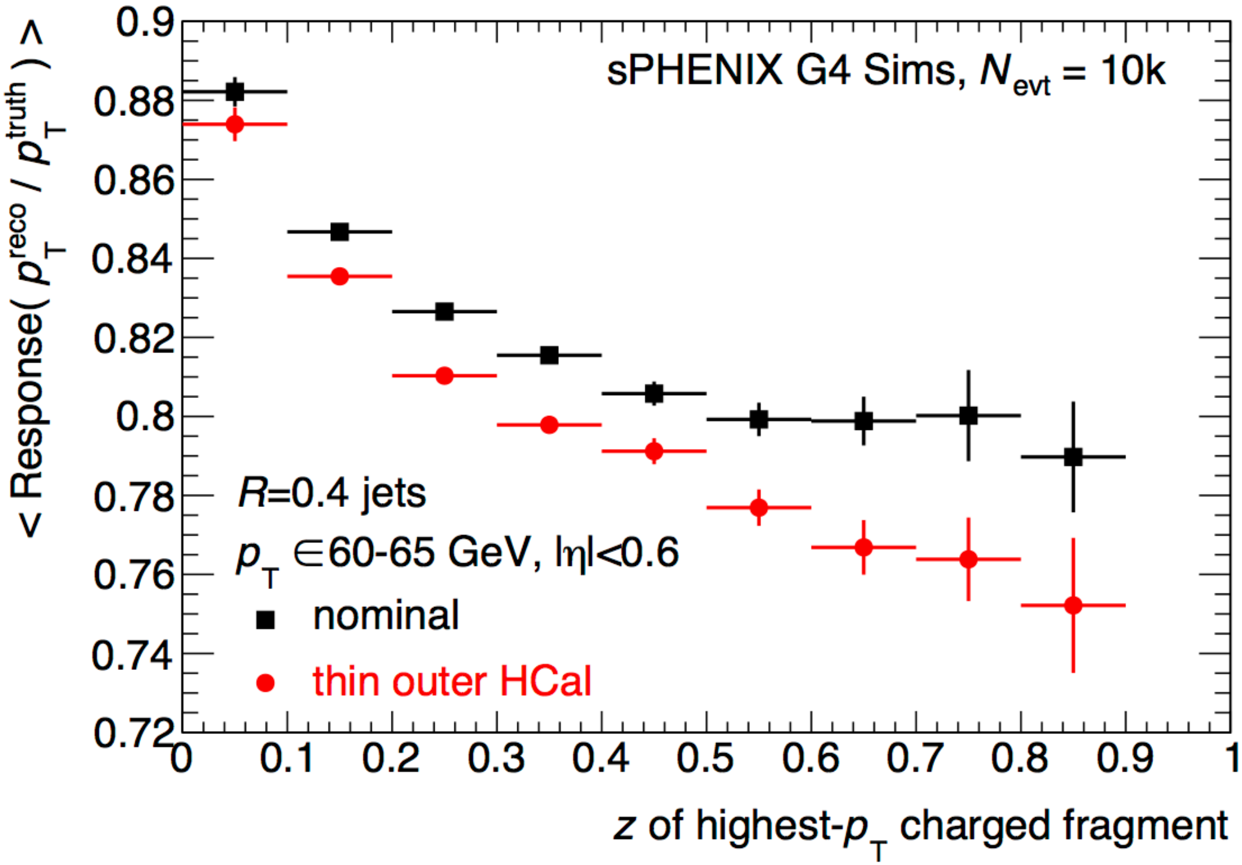


Unfolding Check → Low side tail



- Generate "fake data (blue points) with full GEANT response for thinner Hcal
  - Use single Gaussian to create the Response Matrix
  - Result – Unfolding works with an approximate 5% systematic shift.

Z-Dependent Response

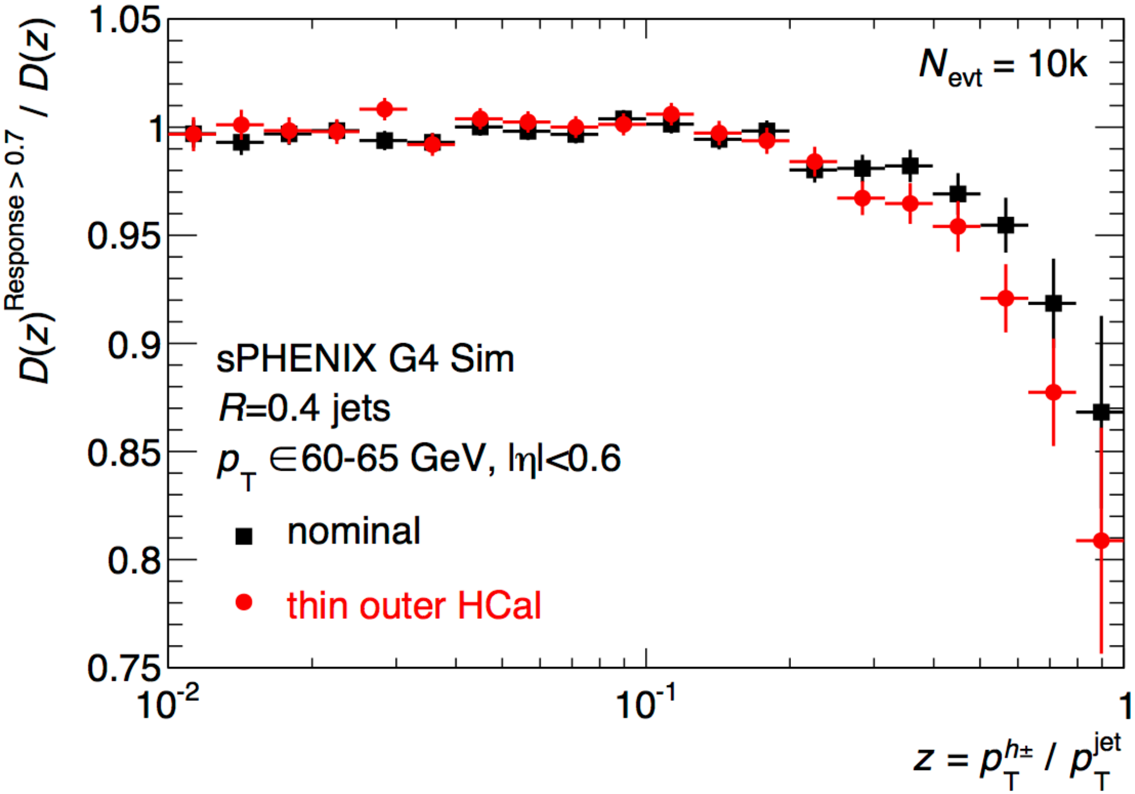


Effect is largest for high p_T jets

What statistics do we expect for high z high p_T jets?

- For both the response decreases with increasing z
  - Nominal: total difference of -8% from z=0 to z → 1
  - Response for thinner HCAL is systematically lower and z-dependent
    - 1% lower at z=0, but 4% lower as z → 1

Z-Dependent Response



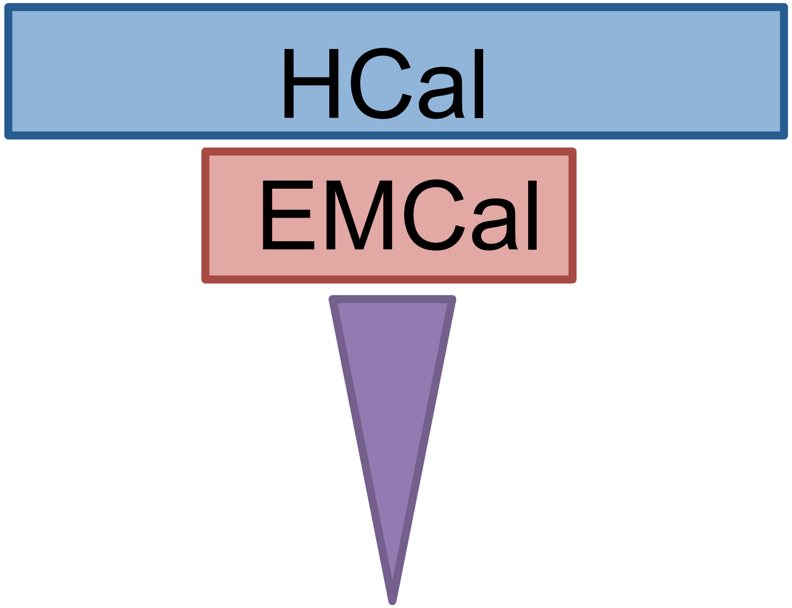
Depletion on previous page can be seen here as well

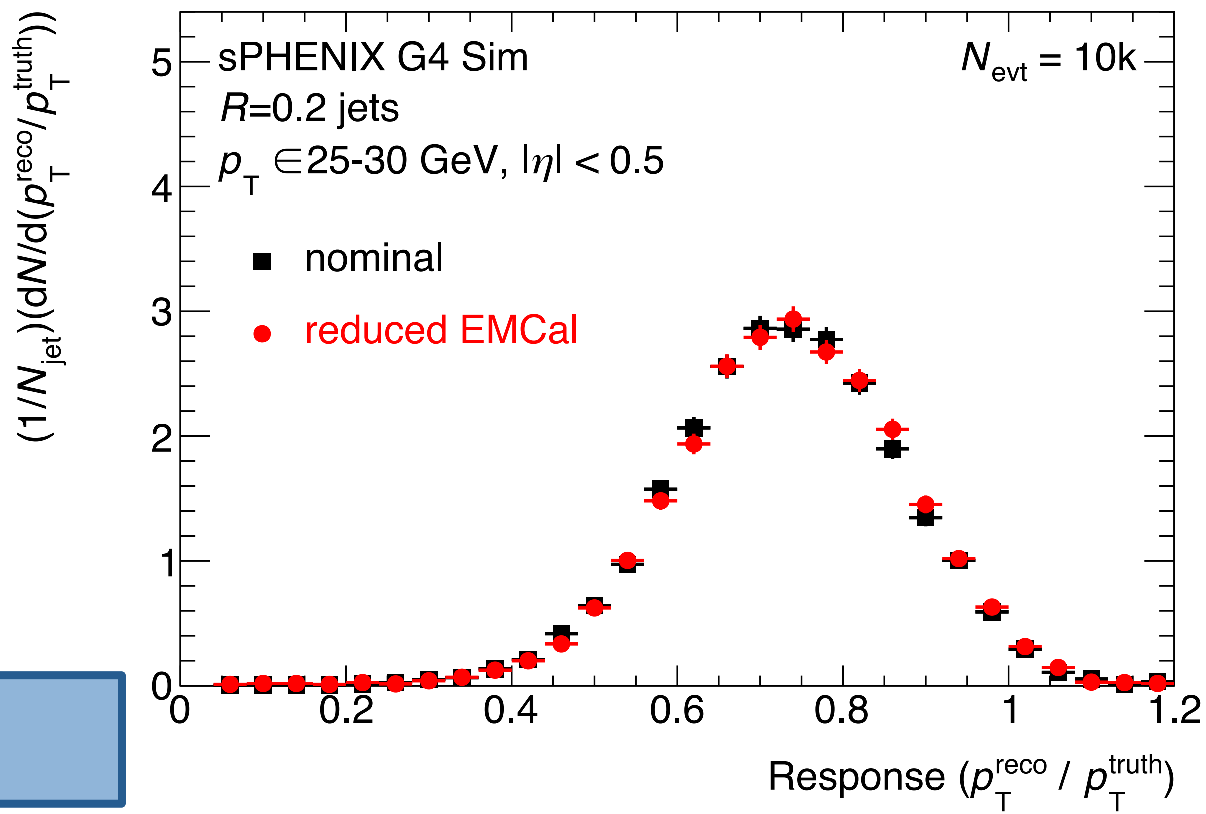
- Truth-level D(z) distribution for jets with a "well-measured" energy differs from that of all jets
  - Well measured = $p_{Treco}/p_{Ttruth} > 0.7$
- Nominal: depletion of up to 10% at large-z relative to all jets
- Thin HCal configuration: depletion is up to 20% at large-z

1/2 EMCal

Fully Contained

- $|\eta| < 0.5$

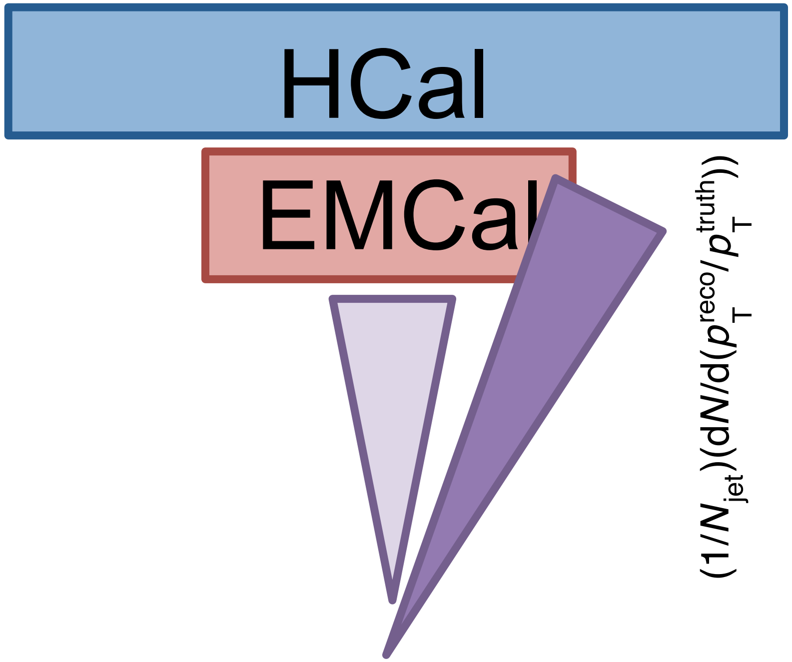


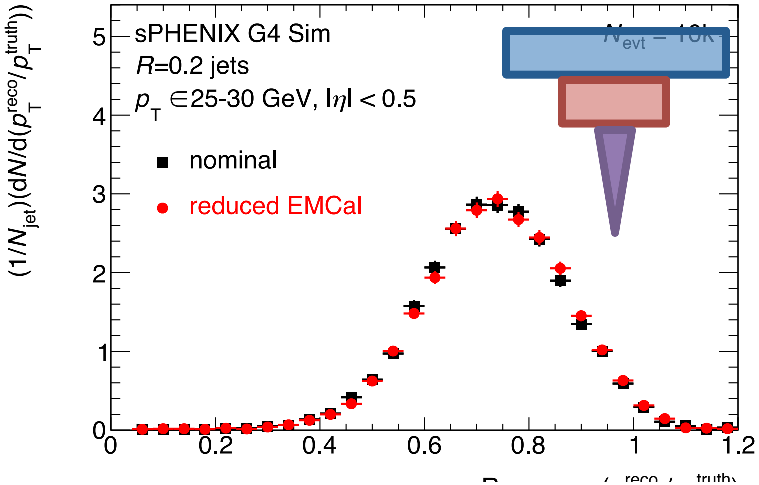


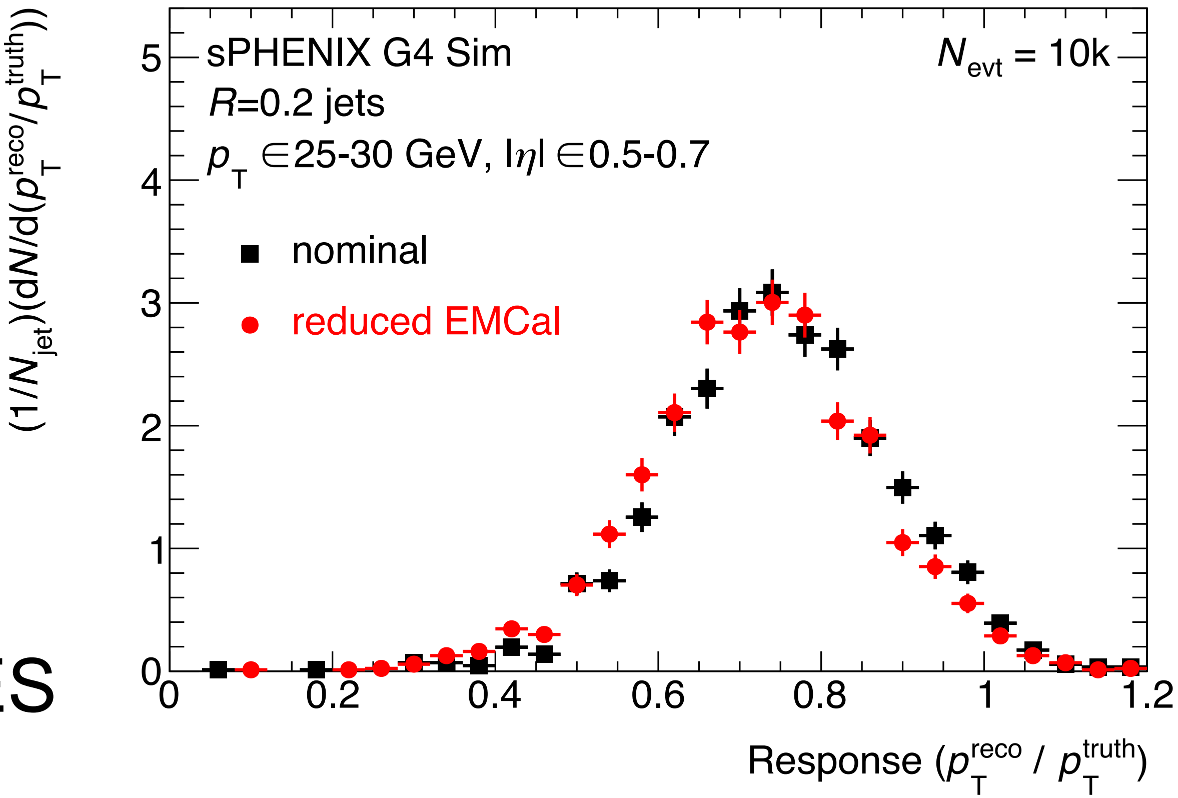
1/2 EMCal

Partially Contained

- $0.5 < |\eta| < 0.7$



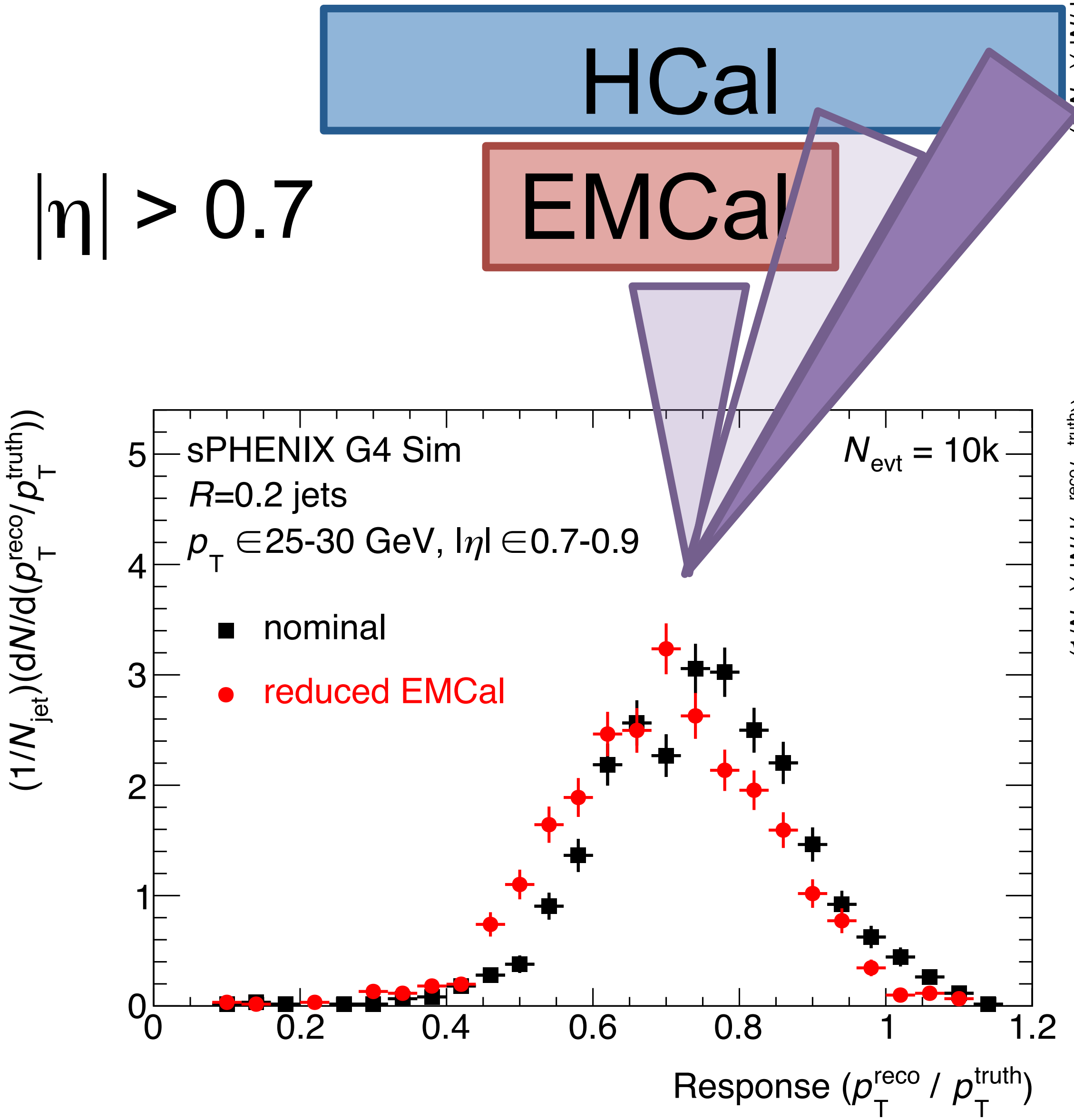


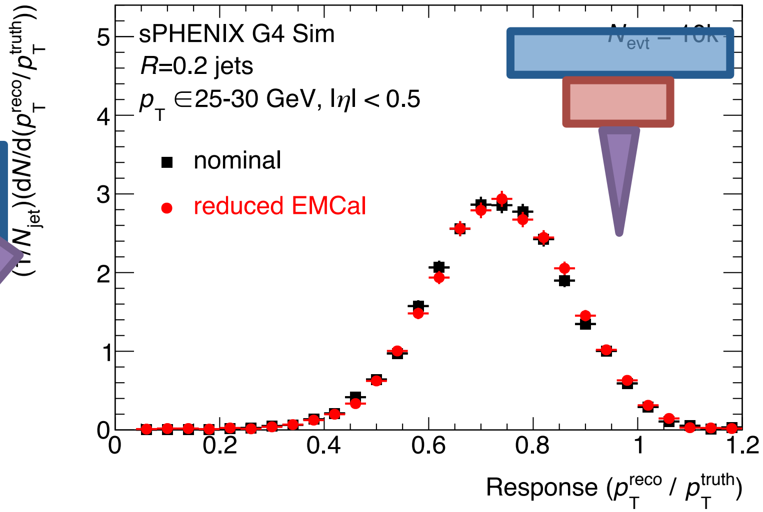


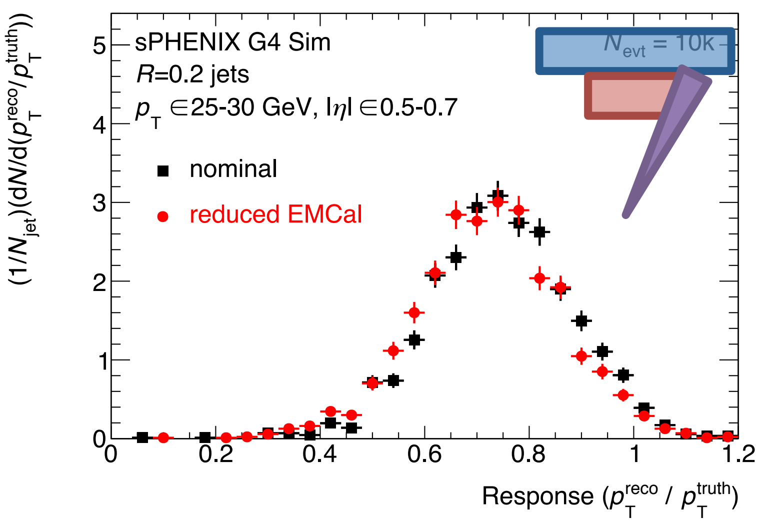
-2.5% shift to the JES

1/2 EMCal

$|\eta| > 0.7$



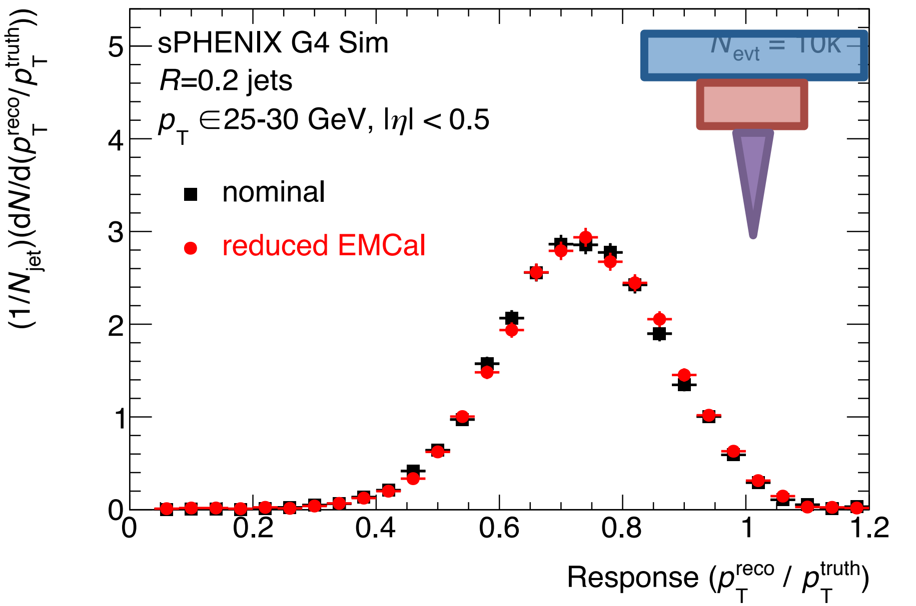


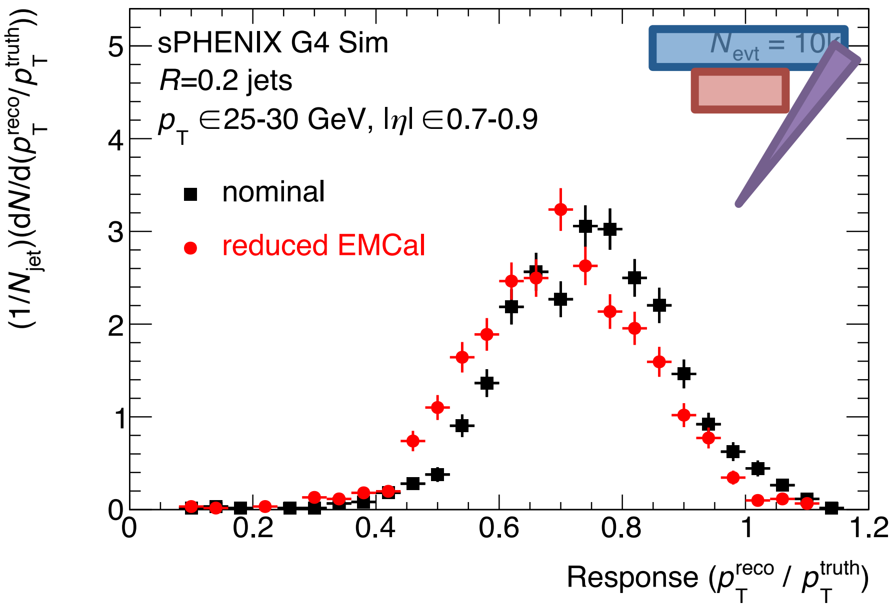


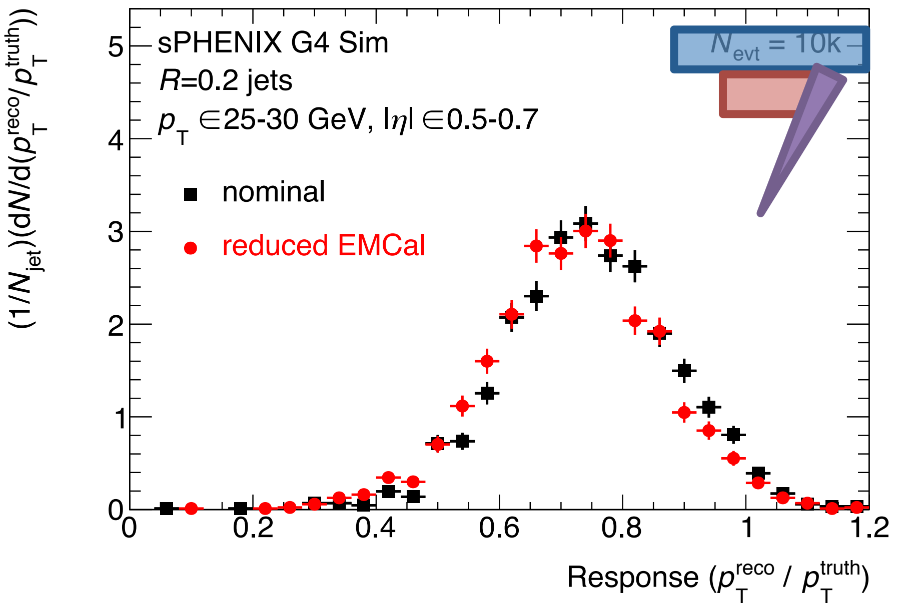
-5% shift to the JES

1/2 EMCal

- HCal can measure the jet energy EM component
- Does not study how detector-level UE fluctuations would be affected
- **Does not quantify sys unc due to η-dependent jet energy correction**
  - Flavor-dependence?
  - Fragmentation?







Tracking Simulation Tasks

Take same set of N_{evt} = 10k, p_T = 50-55 GeV dijet events

- Do tracking-only sim for multiple tracking options
- Repeat for PYTHIA only *and* for HIJING-embedded

For 3 (e.g.) tracking configurations, this is 10k events x 3 configurations x 2 embeddings = 60k w/ tracking-only sim

- **Key observable: efficiency, fake rate, resolution vs. z**

Conclusions

- Thinned outer HCal – Small shift in JES for inclusive jets
  - Z-dependent fragmentation
  - Increased chance of punch-through
- No inner HCal – Causes more of a shift than the thin HCal, likely to be a problem
- Ganged EMCal – No effect on Jet Response
- ½ EMCal
  - JES has a -5% shift for $|\eta| > 0.7$ due to HCal only
  - Unfolding may be complicated in overlap region

Tasks – Looking for volunteers!

- Look at Poynting resolution
- Look at z-dependence of the thin Hcal response for low p_T jets
- Single particle studies with photons
- η-scan of energy deposition in Calorimeters (in progress)
- Check the statistics for high z jet measurements using MIE projections – determine statistics limited case

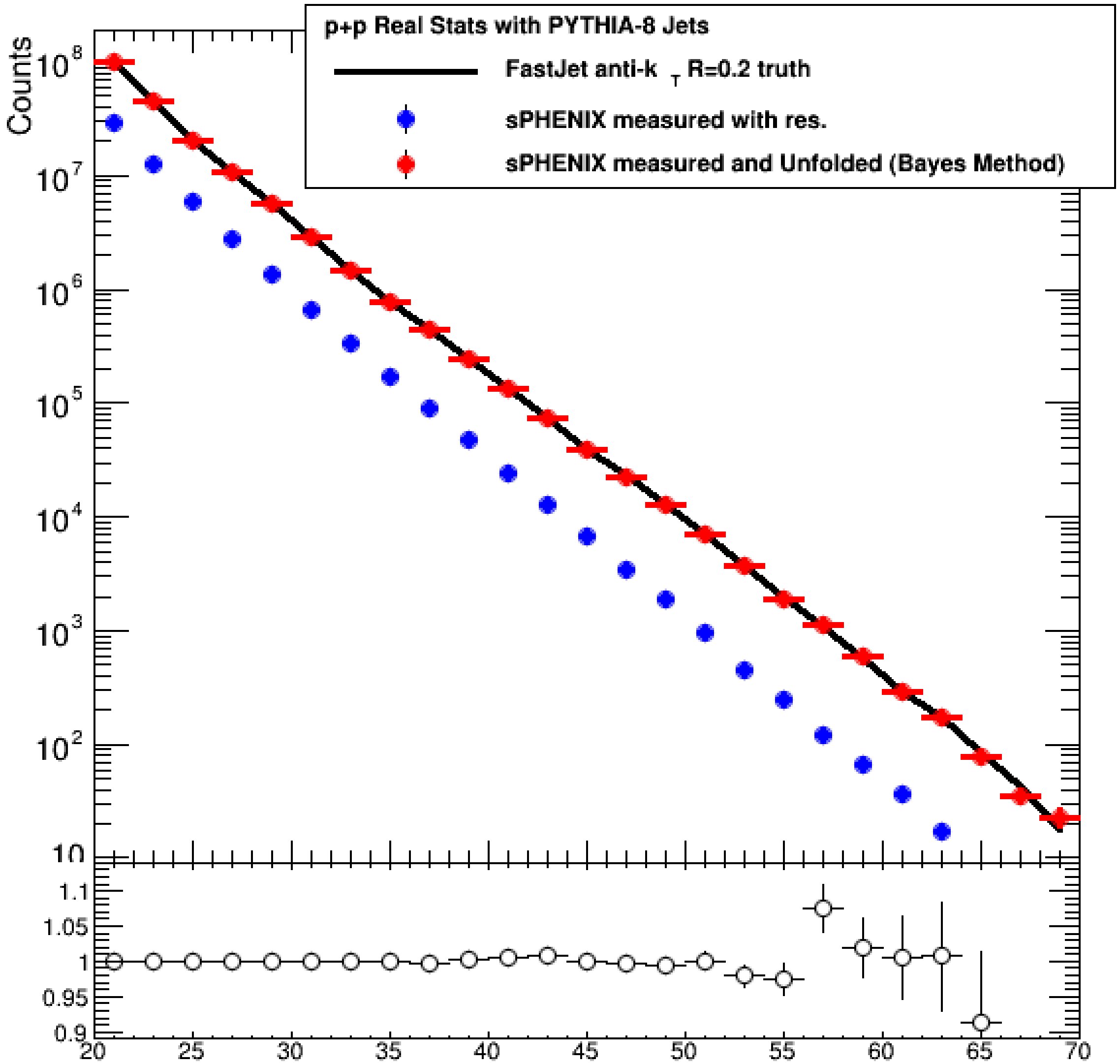
Back-Up

ROOUNFOLD – Case 1

Generate “fake data (blue points) with full GEANT response for thinner Hcal and use the identical function to fill out the Response Matrix.

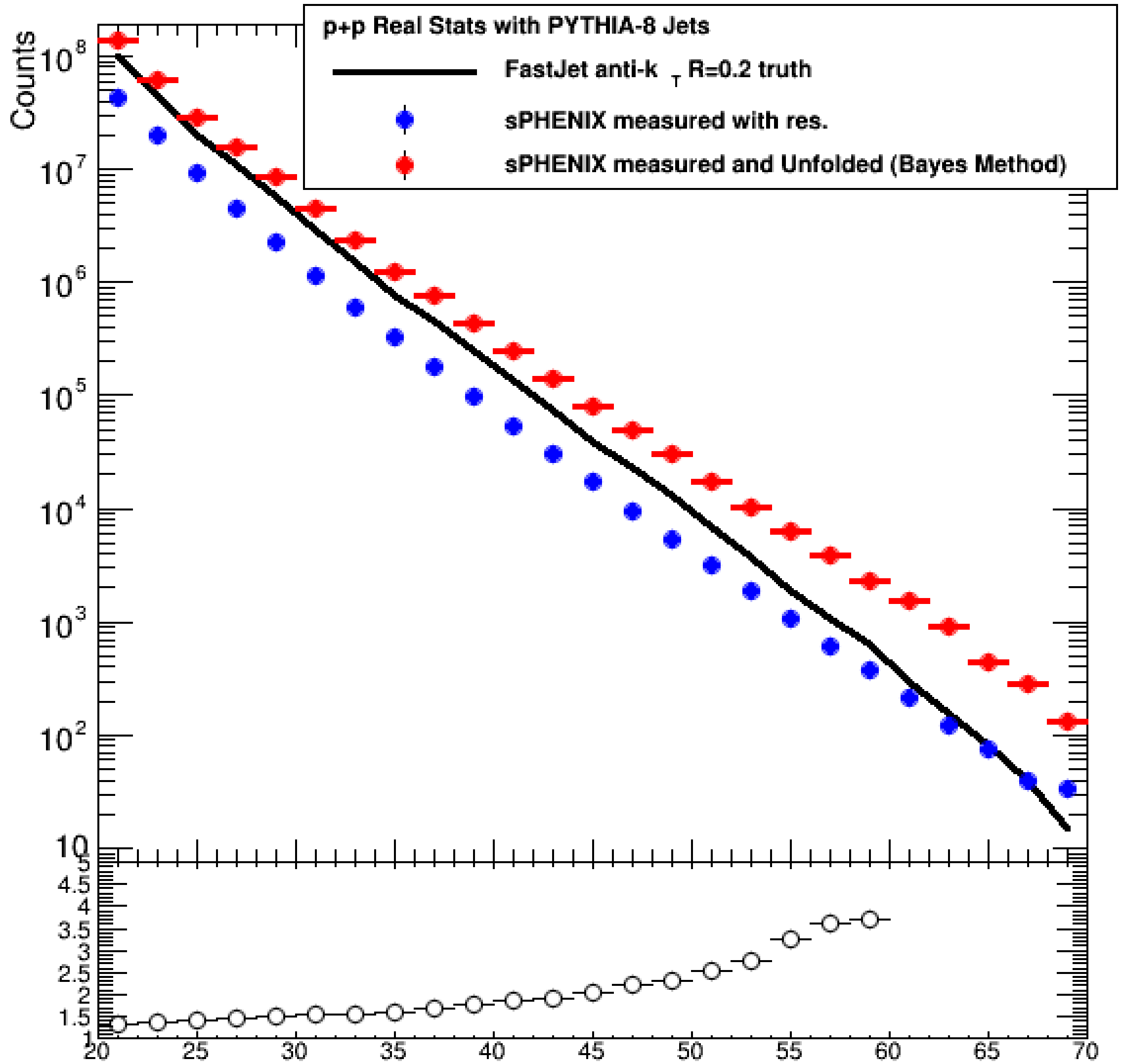
Result – Unfolding works with very good precision.

Jamie Nagle

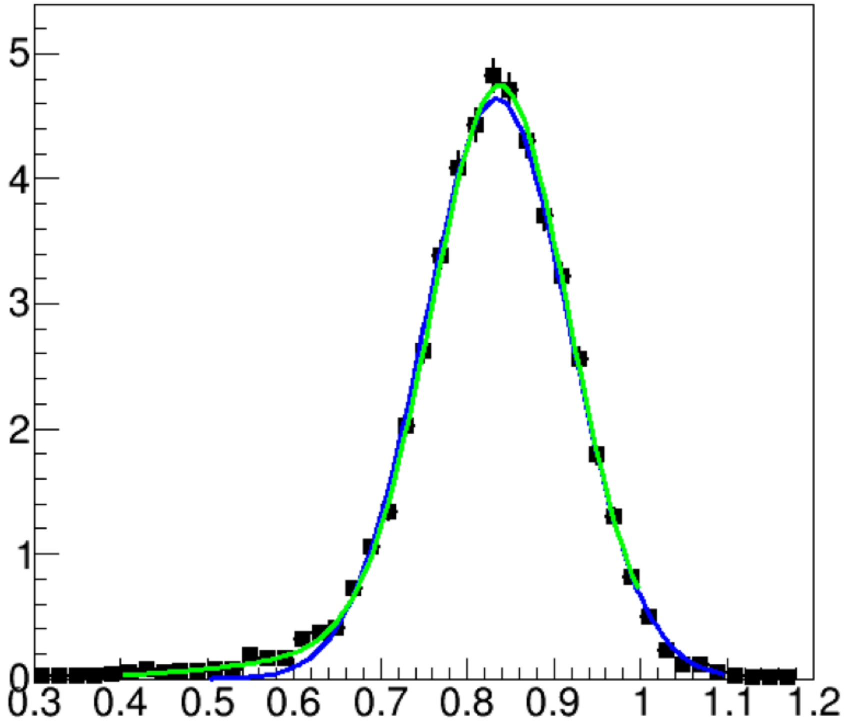


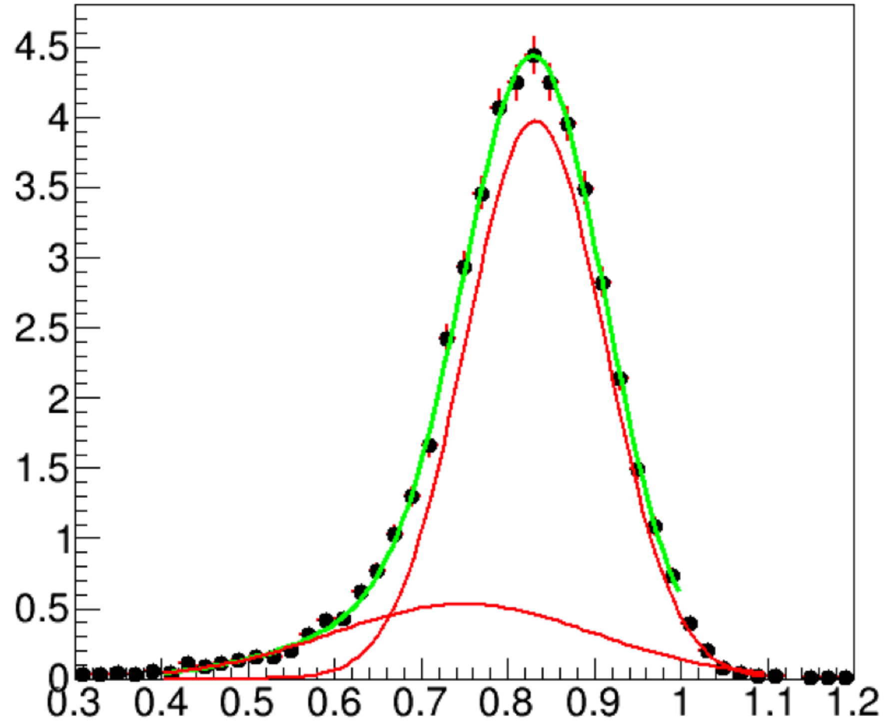
ROOUNFOLD – Case 3

Generate "fake data (blue points) with full GEANT response but shifting the tail to be on the high side and use the just the single Gaussian to fill out the Response Matrix. Result – Large unfolding systematic offset from 50% up to > 400% at high pT.



Jet unfolding and non-Gaussian response

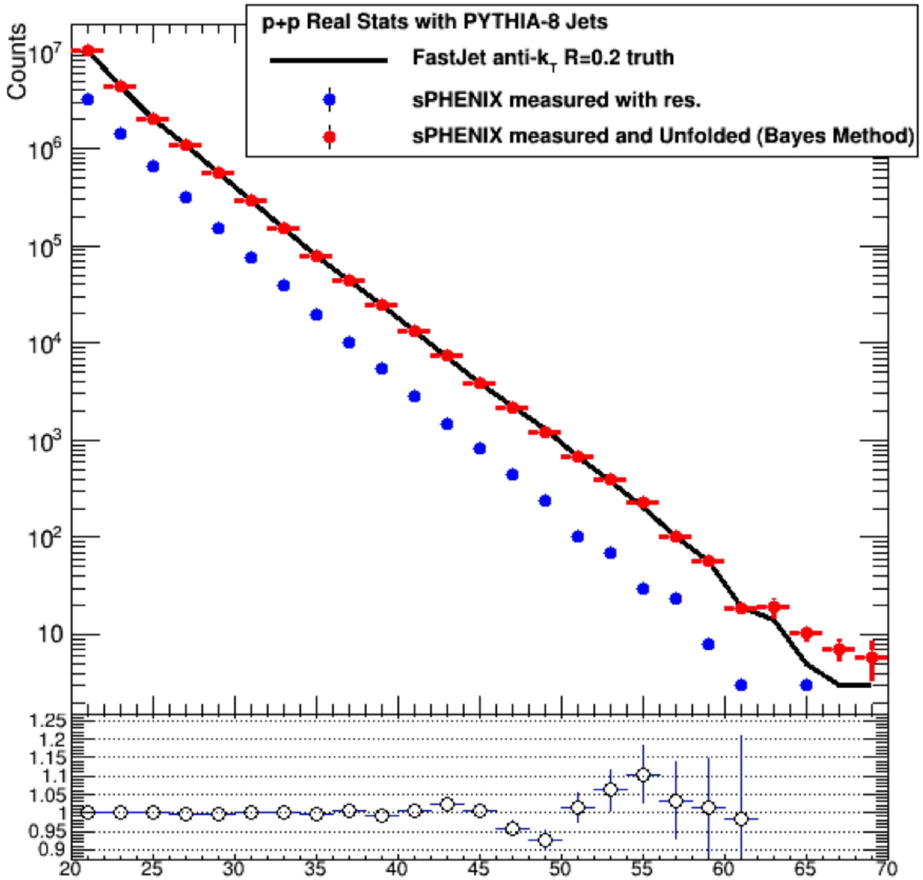


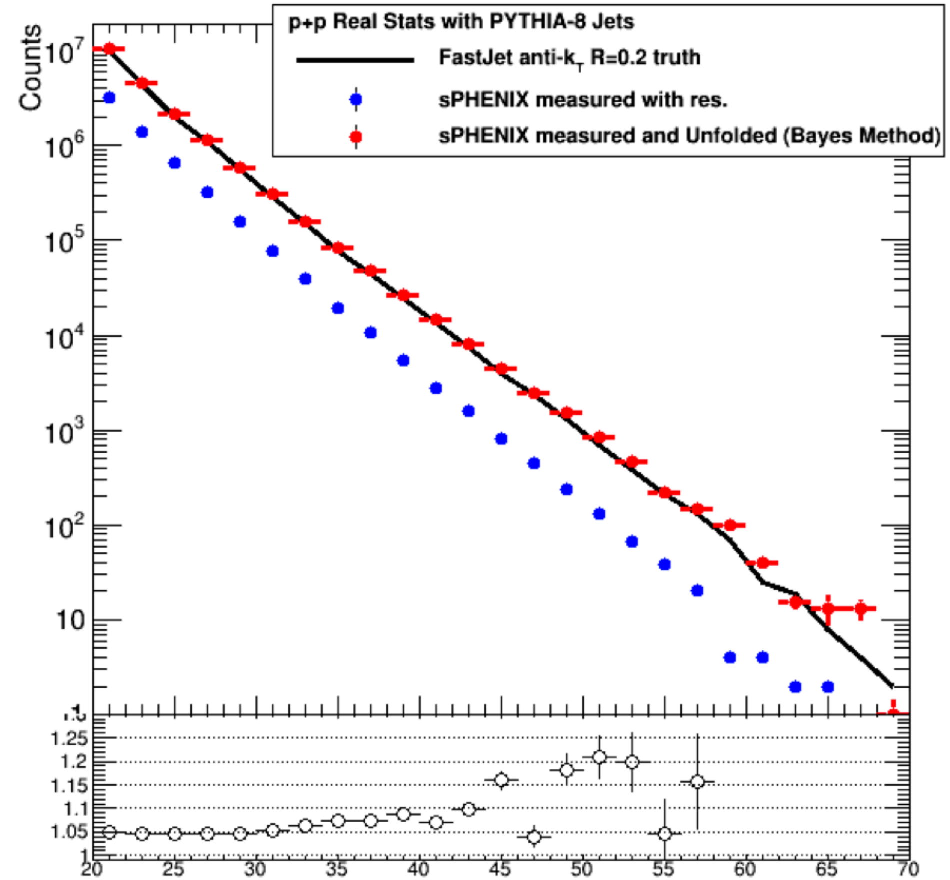


Dennis' GEANT Calorimeter energy response to 50-55 GeV jets.

Dennis' GEANT Calorimeter energy response to 50-55 GeV jets.

Now with thinner outer HCal. Results in second component Gaussian (low-side tail contribution).





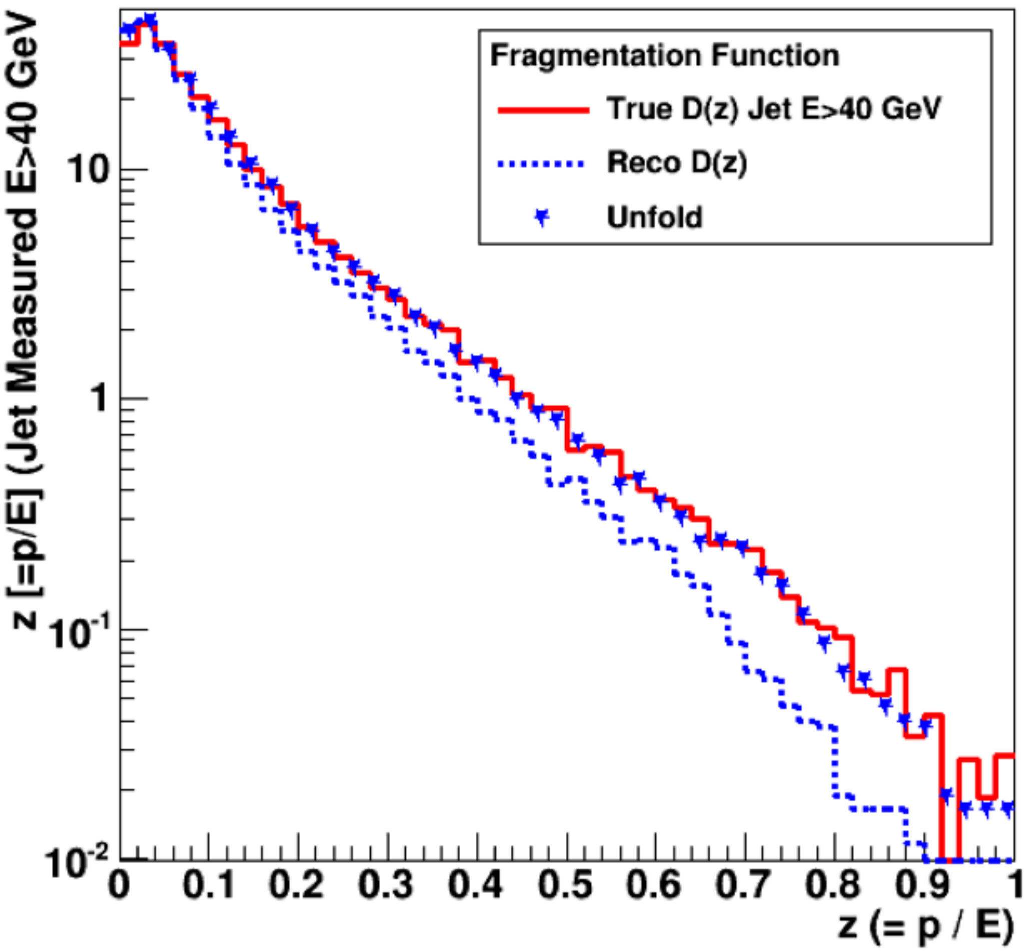
Use identical energy resolution function – including low-side tail with thinner HCal – for “fake data” and “response matrix”.

Bayes unfold works well – resulting unfold/truth ratio around one.

Use energy resolution function with low-side tail for “fake data”, but then generate response matrix completely ignoring the low-side tail (just the peak Gaussian).

Systematic offset of ~ 5% and then larger at the highest pT ~ 15-20%. This is an extreme case (just an initial test).

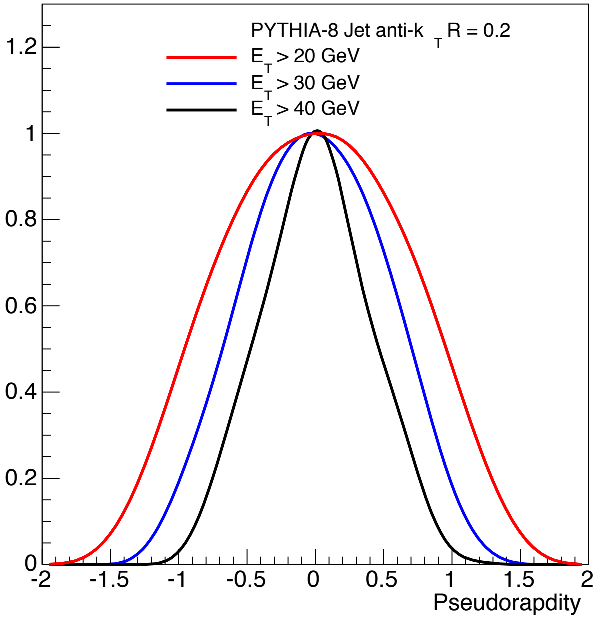
Fragmentation Function MIE



pCDR Statements

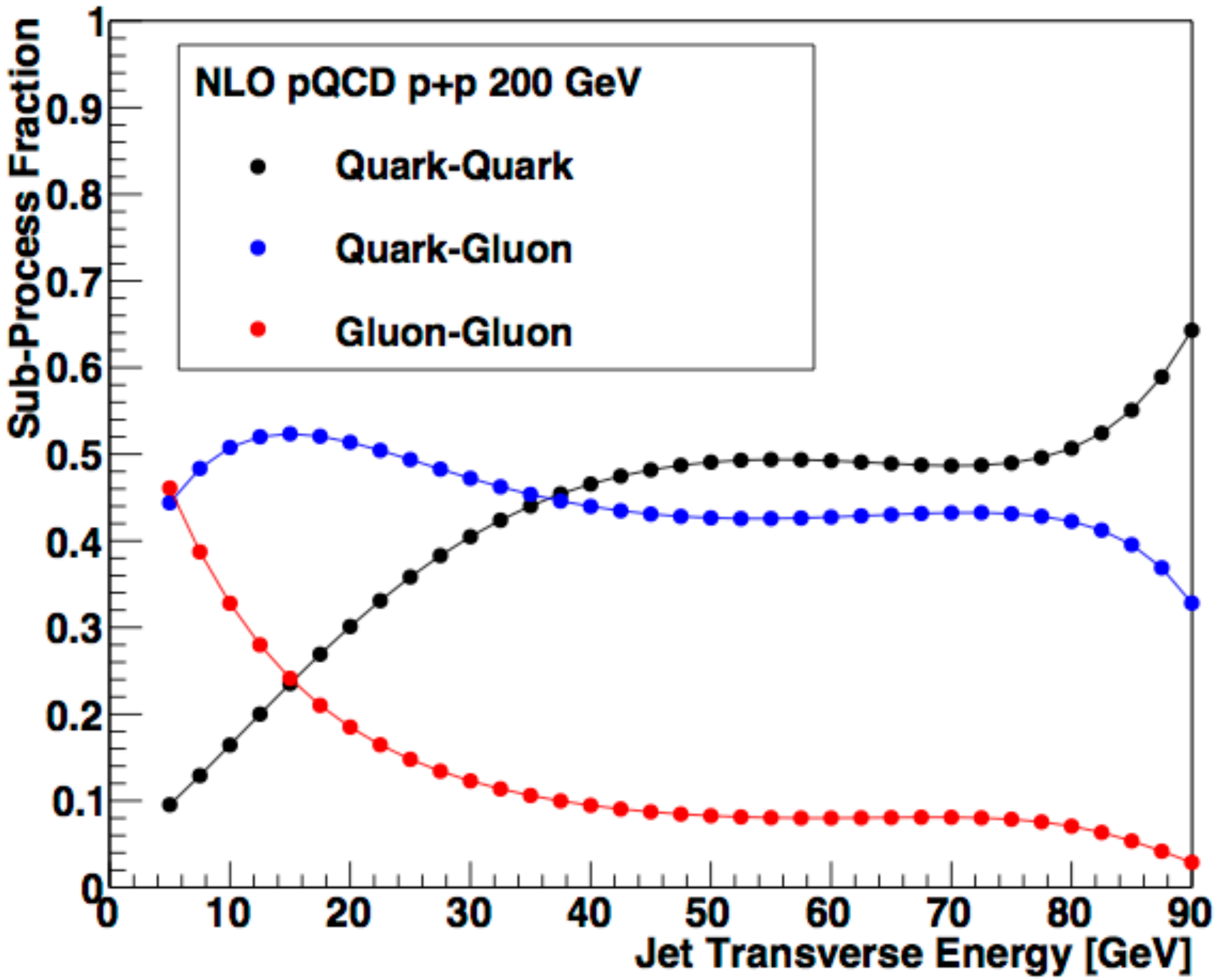
- **Jets** The key to the physics is to cover jet energies of 20–70 GeV, for all centralities, for a range of jet sizes, with high statistics and performance insensitive to the details of jet fragmentation.
  - energy resolution < 120%/$\sqrt{E_{jet}}$ in p+p for R = 0.2–0.4 jets
  - energy resolution < 150%/$\sqrt{E_{jet}}$ in central Au+Au for R = 0.2 jets
  - energy scale uncertainty < 3% for inclusive jets
  - energy resolution, including effect of underlying event, such that scale of unfolding on raw yields is less than a factor of three
  - jets down to R = 0.2 (segmentation no coarser than $\Delta\eta \times \Delta\varphi$ ~ 0.1 × 0.1)
  - underlying event influence event-by-event (large coverage HCal/EMCal)
  - Energy measurement insensitive to softness of fragmentation (quarks or gluons) — HCal + EMCal
  - jet trigger capability in p+p and p+A without jet bias (HCal and EMCal) • rejection (> 95%) of high p_T charged track backgrounds (HCal)

EMCal Acceptance – DiJet containment

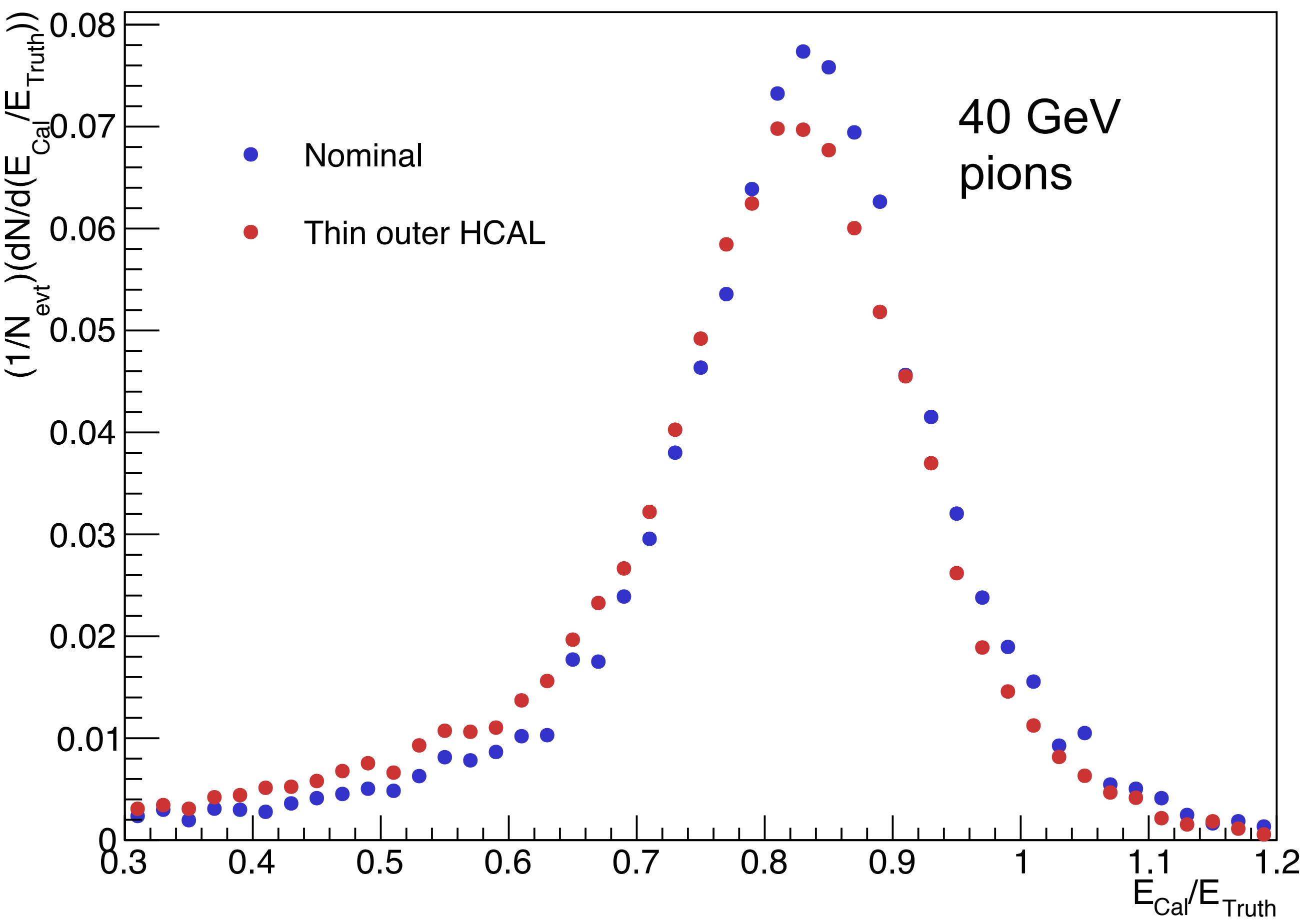


- Reduced acceptance → Reduced DiJet statistics
  - Generator only analysis
  - Especially key for R > 0.2 and/or low p_T jets
  - Note: Pythia 8 tune not identical to the MIE, slightly better performance

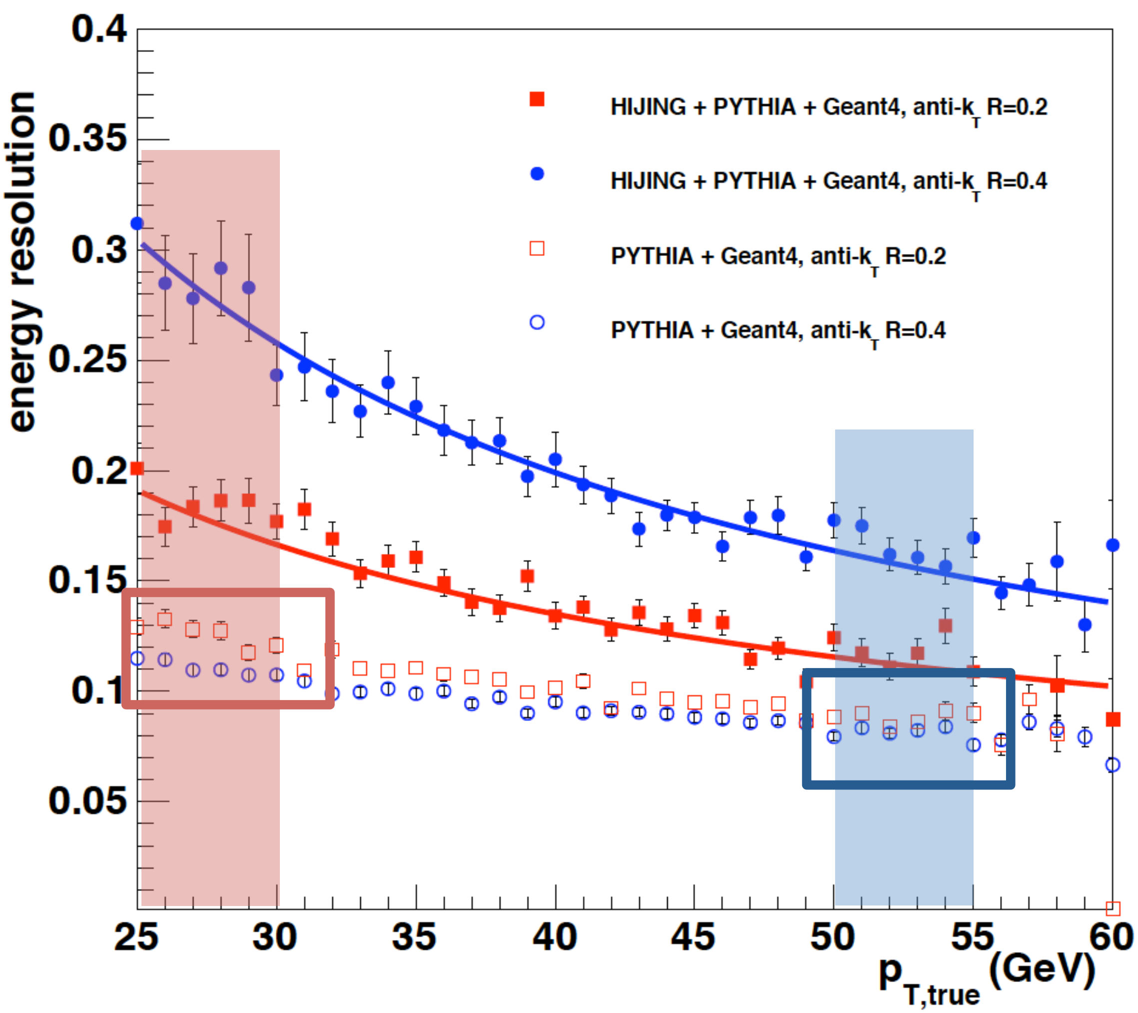
Flavor Content



Total Calorimeter Response (Cluster)



MIE JER versus $p_{T,jet}$

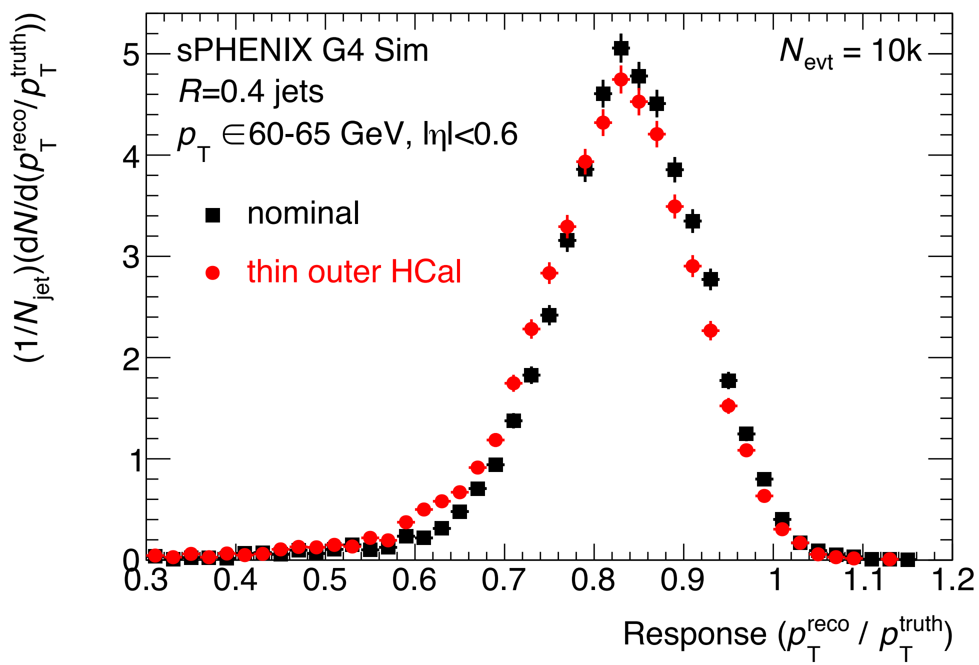


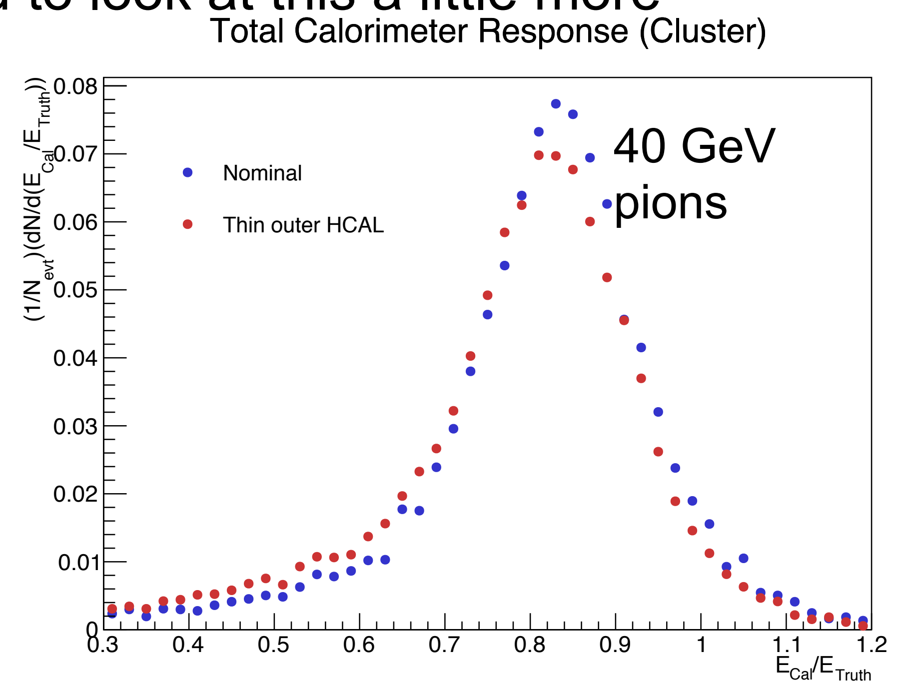
- **R = 0.4** jets effected more by UE
- Similar response in pp to R = 0.2 at $p_T > 50$ GeV
- JER affects unfolding uncertainty
- Ideal $p_{T,Reco}/p_{T,truth} \rightarrow 1$
  - JES

Higher pT

Looked at higher p_T jets (60 - 65 GeV) this morning

- Result is similar to 50 – 55 GeV
- Additionally looked at 40 GeV pions → high z particles
- Very similar to jet results → 40 GeV hadrons do not seem to be punching through
- Preliminary from this morning, we need to look at this a little more

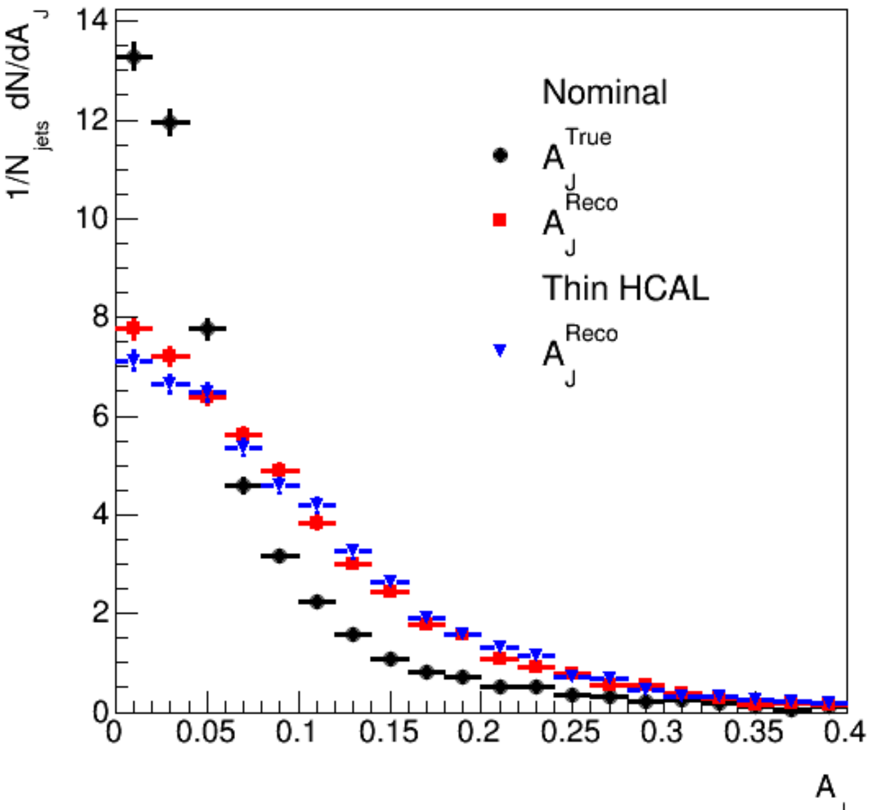




Jet Response for DiJet A_J Measurement

Difference in Jet Response between nominal and thin HCal has a minimal effect on reconstructed A_J

- Does not account for UE Fluctuations



$$A_J = \frac{p_{T,Leading} - p_{T,Subleading}}{p_{T,Leading} + p_{T,Subleading}}$$

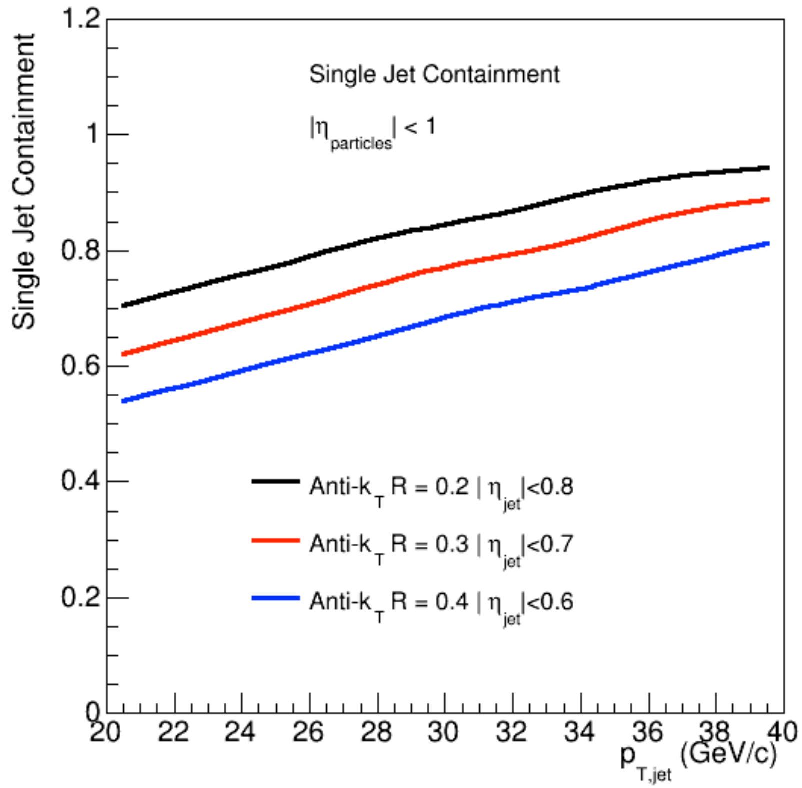
$p_{T,Reco} > 10$ GeV

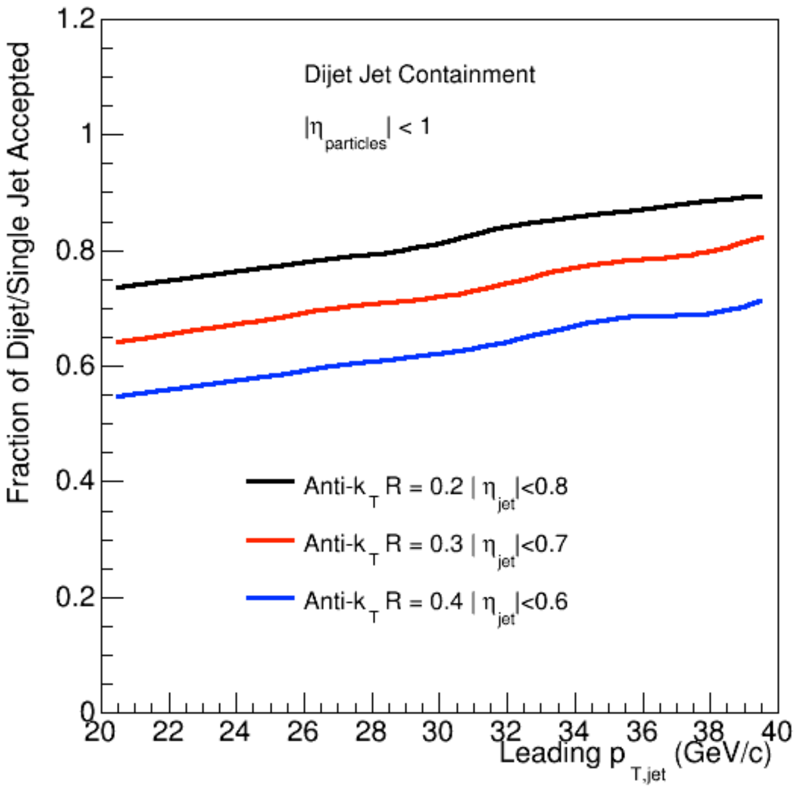
$|\Delta\phi| > 2.35$

Jet Containment vs R – MIE

For fully contained jets, acceptance is reduced with increased R

- For R = 0.4 jets at 20 GeV, acceptance reduces the total reconstructed dijet cross-section ~30%
- Conditional cross-section is ~70% for R = 0.2 jets

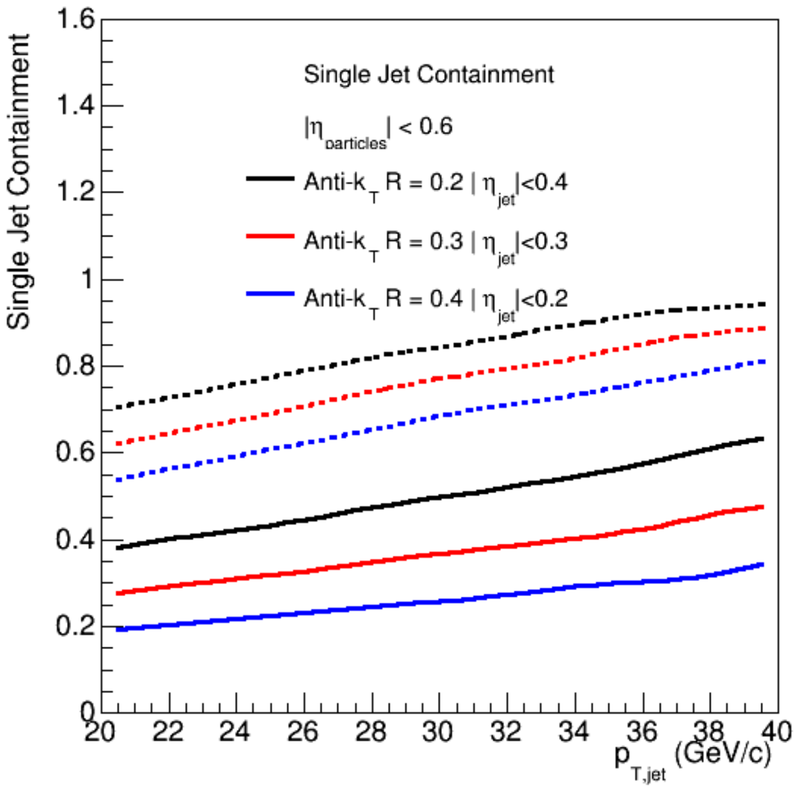


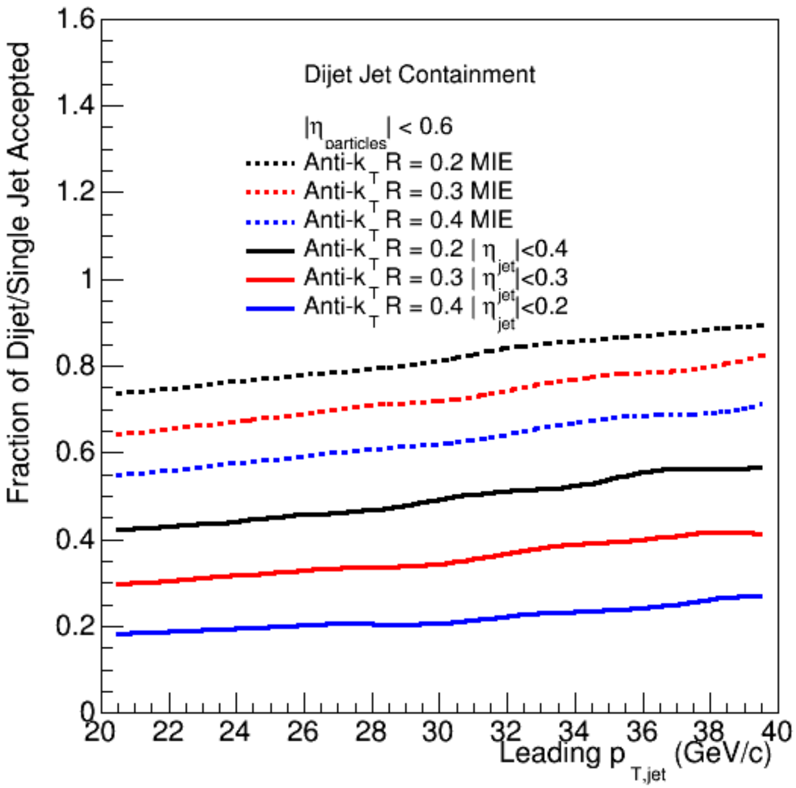


Jet Containment vs R – Reduced EMCAL

For R = 0.4 jets at 20 GeV, acceptance reduces the total reconstructed dijet cross-section to ~4% from 30% from the MIE

- An order of magnitude different



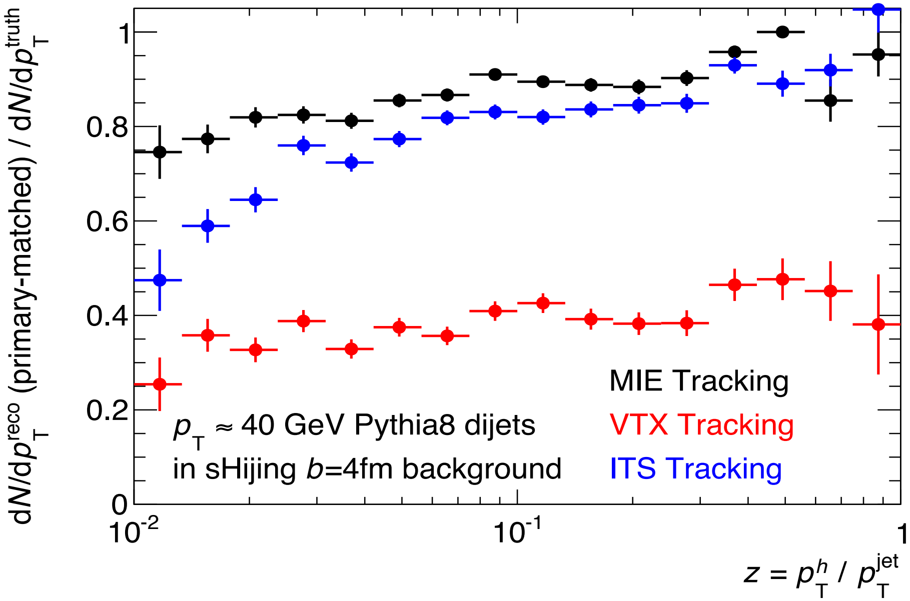


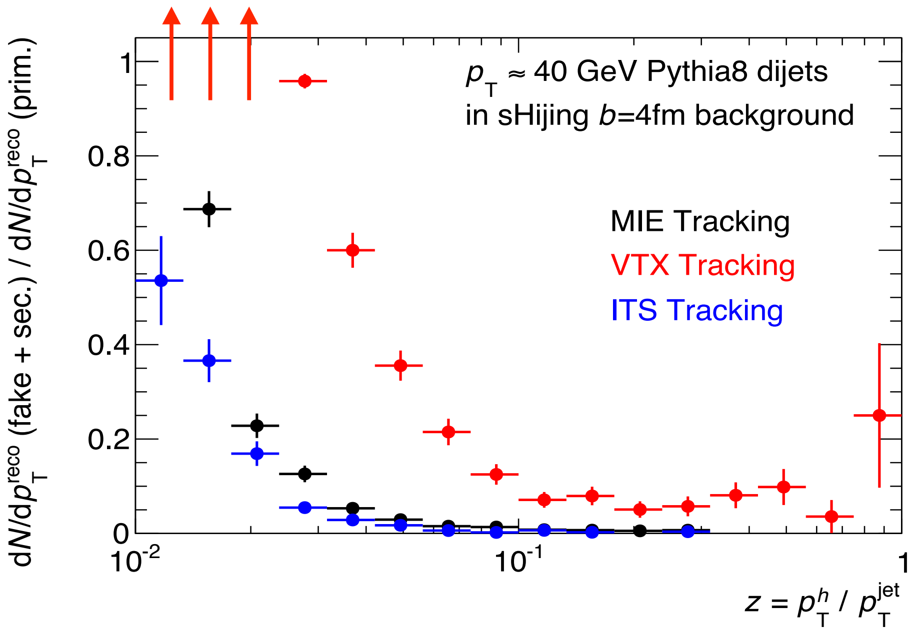
Previous Tracking Evaluation Work

G4 tracking studies have been underway in Simulations meeting

- On next slide, study of charged particle performance for 40 GeV dijets, with some current (at the time) tracking options
- Note: “VTX” on next slide is 2 layers with existing dead areas, not one reconfigured layer...

- Comparing tracking configurations: **MIE** ideal 7-layer silicon, reused **VTX** pixels + ganged strips, 7 layer ALICE **ITS**
- G4 tracking simulated, embedded in b=4fm Hijing background
- Fragmentation functions for p_T ~40 GeV dijets





Truth-matched $\dfrac{dN / dp_T^{reco}}{dN / dp_T^{truth}}$

Fake+secondary truth-matched $\dfrac{dN / dp_T^{reco}}{dN / dp_T^{reco}}$

How big are corrections for efficiency and p_T resolution together?

What is the relative fake rate inside jet cone?